Electro-Motive Diesel, Inc. Locomotive Experiences

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Presentation Topics

- Emissions Technology Transfer to Locomotives from Other Vehicles
- EMD Tier 2 Locomotives
  - 67% NOx emissions reduction
  - 50% CO, HC, PM emissions reduction
  - Reduced visible smoke

Do on-highway engines "show the way" for locomotives?

- Standards and technology cascade from on-highway to off-highway to locomotives and marine vessels.

But . . .

- Major locomotive builders do not build on- or off-highway engines.
- Technology successful in truck engines often does not transfer well to locomotives.

Major locomotive builders do not build truck engines.

- On-highway engine builders:
  - Caterpillar
  - Cummins
  - Detroit Diesel
  - International
  - Mack
- Locomotive engine builders
  - General Electric
  - Electro-Motive
  - Caterpillar

Technology successful in truck engines often does not transfer well to locomotives.

- Differing operating cycles
  - On-highway: Transients in power and speed
  - Locomotive: Steady-state
- Differing operating modes
  - On-highway: High power = High speed
  - Locomotive: High power = Low speed
- Packaging constraints
- Phasing-in of fuel sulfur regulations

Differing operating cycles
Example: Electronic injection control

- On-highway vehicles have made improvements in fuel economy and emissions with electronic engine control, largely through management of transients.
- Locomotives operate at steady state.
  - Mechanical control works as well as electronic
  - Slight electronic advantages:
    - ✓ Durability of settings
    - ✓ Control of transient smoke

Differing operating modes Example: Air-to-Air Aftercooling

- In on-highway vehicles, high power is used to go fast.
- In locomotives, high power is frequently used to haul heavy cargo slowly.
- It’s always known which end of an on-highway tractor is the front; with locomotives it’s 50-50.
- Unlike trucks, locomotives are subjected to very high ambient temperatures in tunnel operation.
- Result: Air-to-air is a relatively easy application on a truck; on a locomotive space must be found for it, all air must be moved by fans, and sometimes the cooling is absent.
  - Lower emissions benefit
  - Less fuel consumption improvement
  - Loss of aftercooling capability in tunnels

Packaging Constraints Example: Aftertreatment

- Locomotives are limited in size and weight
  - Approx. 16’ 1” high x 10’ 8” wide x 80’ long max.
  - Approx. 420,000 lbs maximum weight
- Functional constraints
  - Locomotive has to carry fuel for operational range
  - Crew has to be able to pass between units in consist
  - Crew has to be able to see along locomotive to monitor train
  - Locomotive design has to allow for maintenance

Packaging Constraints Example: Aftertreatment (2)

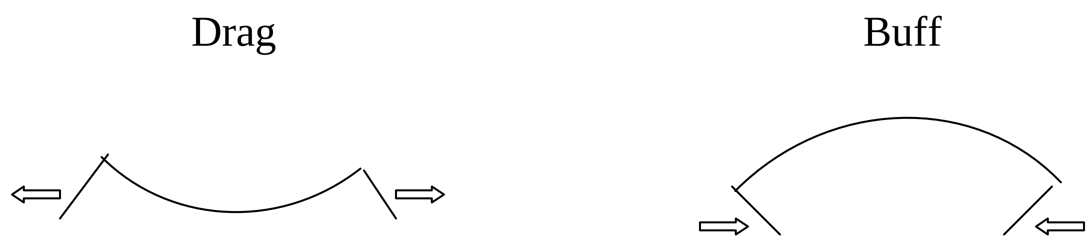
- Locomotive is full of machinery
  - Engine, transmission, fuel tankage, support systems, trucks
  - Crew space and crew amenities
  - Empty space used for maintenance requirements
- Space for aftertreatment reactors and required reagents is limited
  - Space of current silencer (approx. 55” wide x 37” long x 30” high, about 35 cu. ft., about the size of an office desk).
  - Current estimate of particulate trap 47 cu. ft., elements only, not allowing for ductwork
- Development for high effectiveness in small space required.

Other issues in technology transfer: Shock loads

- Locomotives are subject to longitudinal shock loading:
  - Slack action in train
  - Hard coupling
- Design criterion: $\pm$3 g's acceleration - Would wreck a car or truck
- Shock loads are a challenge for heavy things mounted up high, e. g. ceramic catalyst elements.

Other issues in technology transfer: Drag and buff loads

- In operation, locomotives experience tensile (drag) and compressive (buff) loads.
- The loads bend the locomotive:



Result: Piping in locomotive (for cooling system, aftertreatment, etc.) must be designed to accommodate several inches of relative motion.

Ultra-Low Sulfur Diesel Fuel

- Required for aftertreatment, to prevent:
  - Diesel oxidation catalysts: Sulfate particulate formation
  - Particulate traps:
    - ✓ Passivation of catalysts
    - ✓ Sulfate fouling of filter
  - Selective catalytic reduction of NOx: Ammonium sulfate formation
  - NOx adsorbers: Catalyst passivation
- Nationwide ULSD availability required for successful line haul locomotive applications
  - Truck ULSD: 2006
  - Nonroad ULSD: 2010
  - Rail and marine ULSD: 2012

SD70ACe Locomotive

- 4300 traction horsepower freight locomotive
- AC traction motors
- EPA Tier 2 emissions certified
- 3 for 5 replacement of 1970's locomotives
- Automatic Engine Stop-Start (AESS) for idle minimization is standard equipment
- Impact resistant fuel tank minimizes spills and leakage
- Two hundred fifty-seven delivered to date.

SD70M-2 Locomotive

- 4000–4300 traction horsepower freight locomotive
- DC traction motors
- EPA Tier 2 emissions certified
- 3 for 4 replacement of 1970’s locomotives
- AESS is standard equipment
- Impact resistant fuel tank minimizes spills and leakage
- One hundred thirty-five delivered to date.

Tier 2 Switcher: GP20D

- 2000 traction horsepower branch line and switching locomotive
- DC traction motors
- EPA Tier 2 emissions certified
- 15% better fuel efficiency than older switchers

- Satisfies FRA and AAR crashworthiness requirements
- 13 built

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